

# Patient Alignment Technologies

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**ProCure**

# Learning Objectives

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*After this lecture the attendees should have*

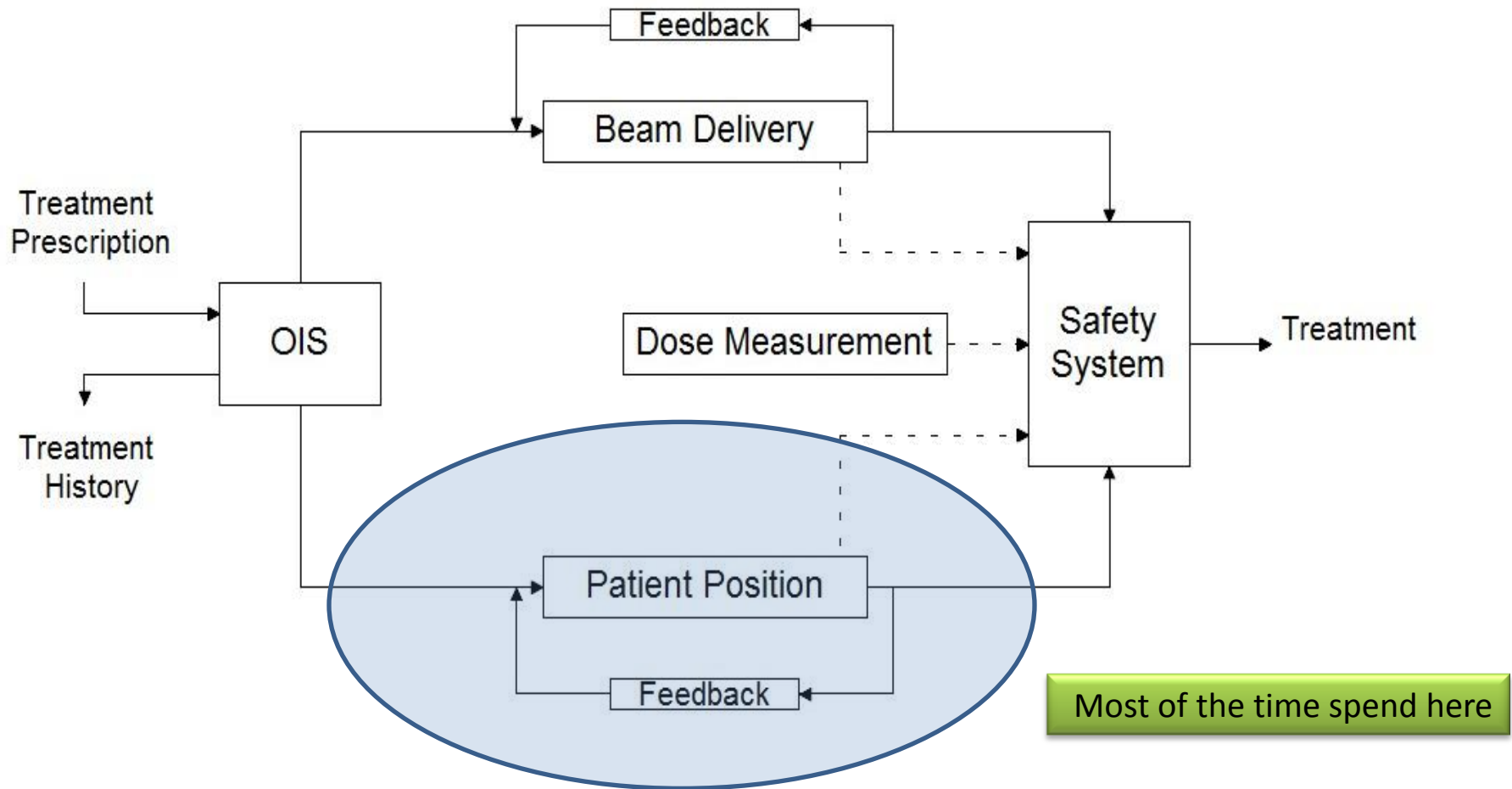
- A better understanding of Patient Positioning Systems (PPS)
- Knowledge about state of the art Patient Alignment Systems (PAS).
- Understand the needs for new thinking towards patient positioning for proton therapy.

# IGRT + Proton Therapy

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- Proton Therapy introduced Image Guided Radiation Therapy (IGRT) to the field of Radiation Therapy.
- Protons have always been delivered while using some sort of imaging during the setup process.
- However – today Ion Therapy Systems are not properly equipped with IGRT systems as compared to Photon therapy systems.

# The Radiation Therapy Process – Control diagram



# What is required in the Patient Alignment Process?

- Patient Positioner
  - to move the patient accurately into position
  - to keep the patient in position
- Immobilization system
- Imaging + Localization System
  - to know where the target is
  - to ensure the target remains in position

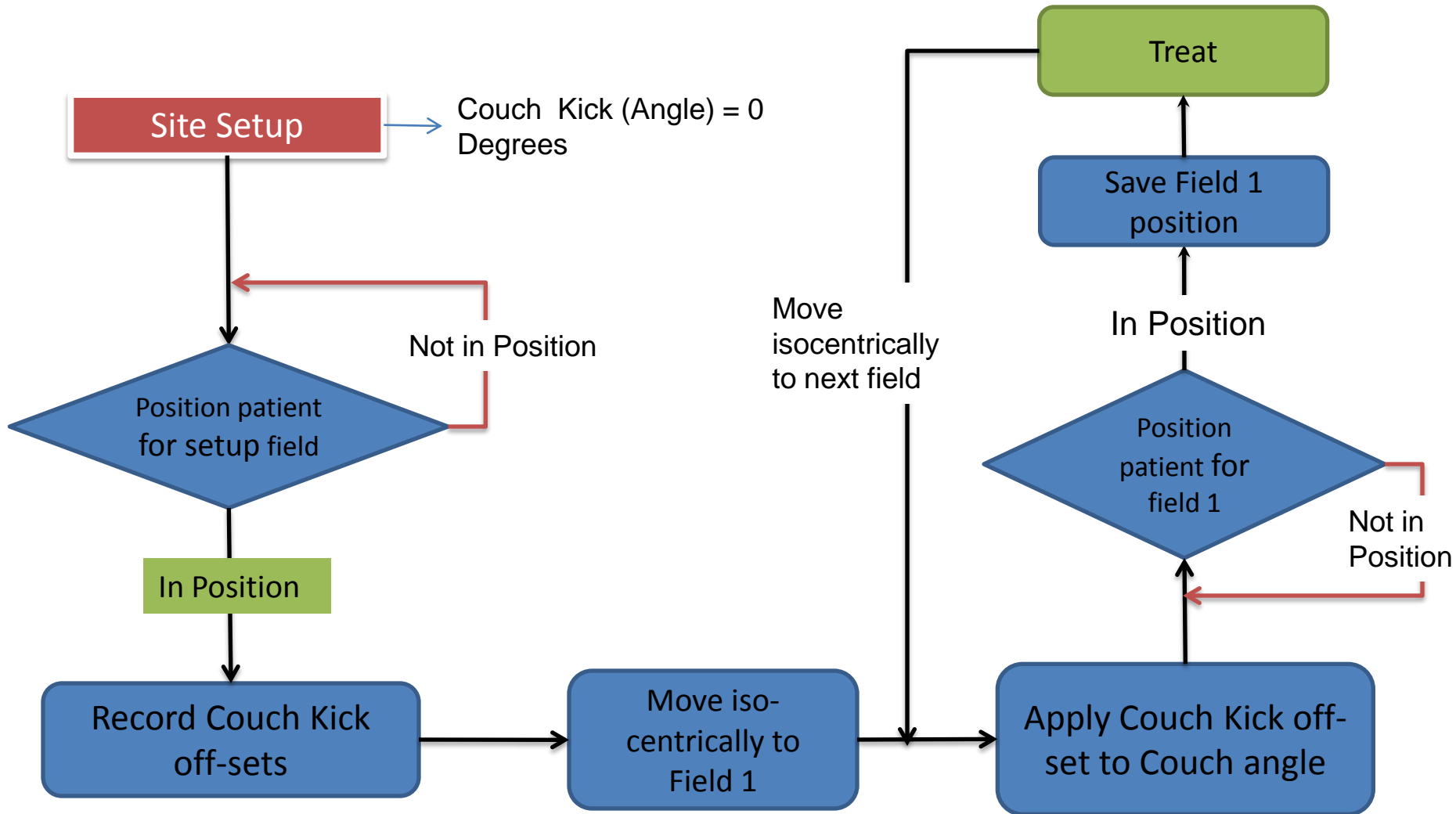
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1

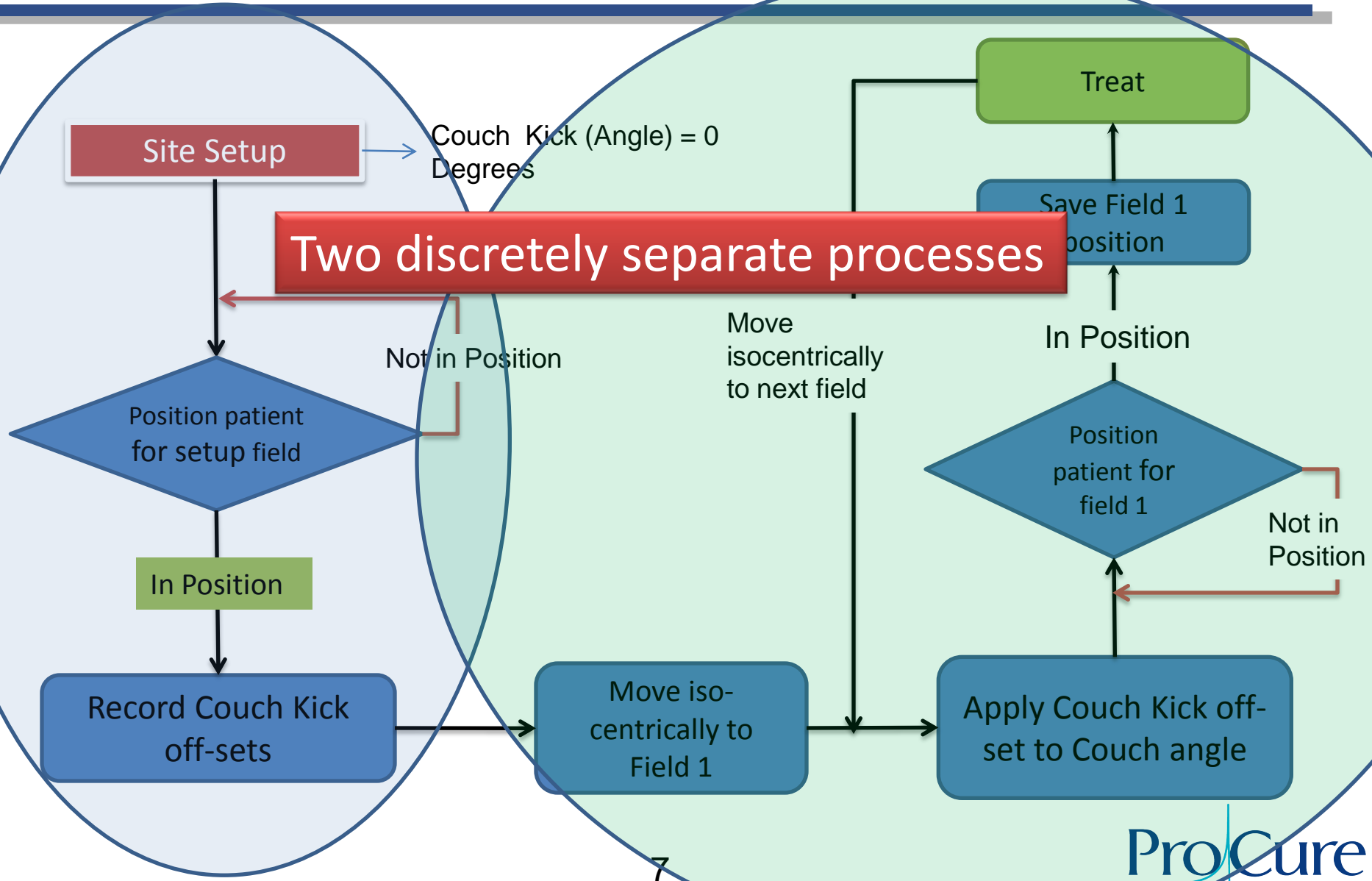
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- ~~• Oncology information System
  - provide the information
  - track and record the process~~

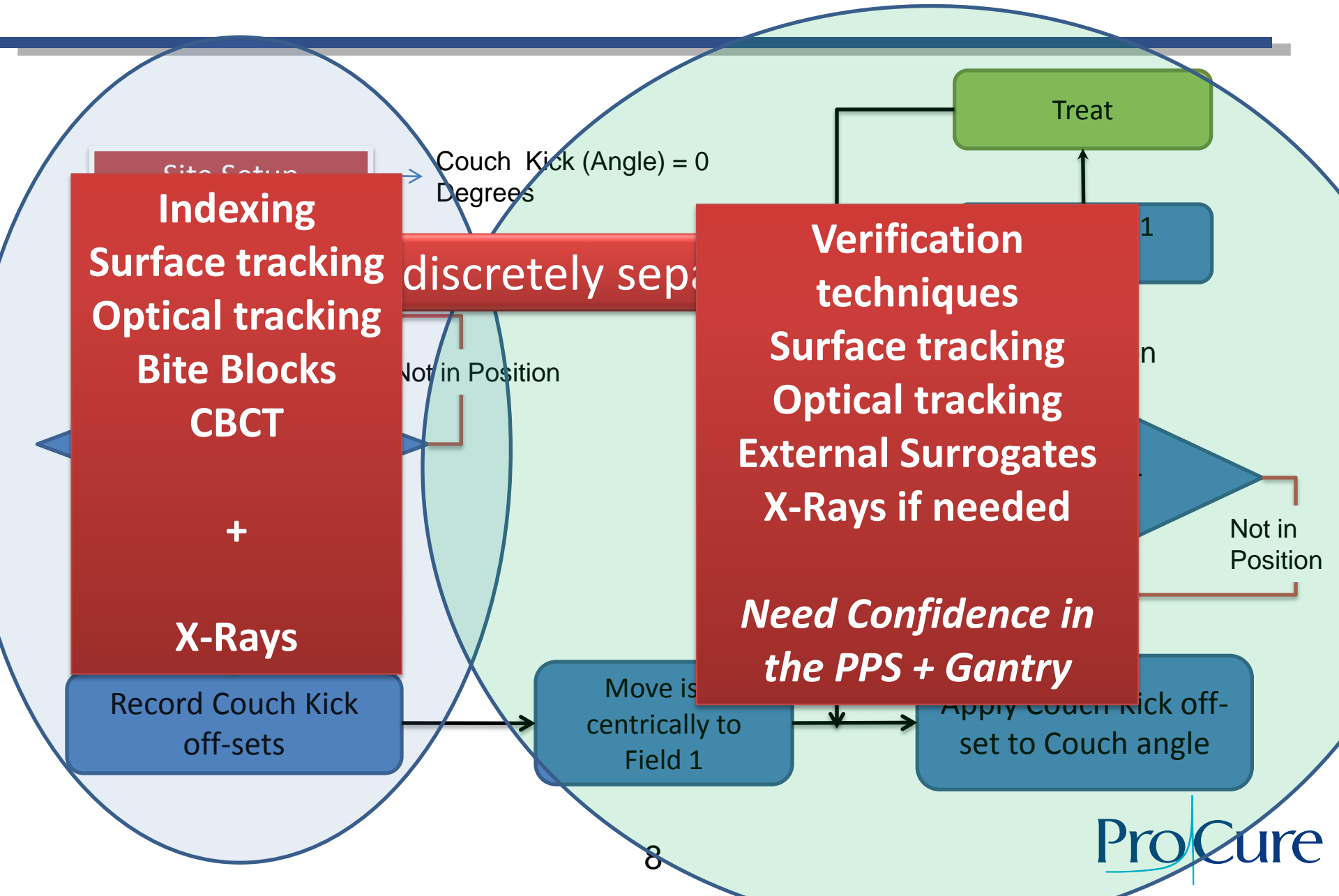
# Patient Alignment Workflow



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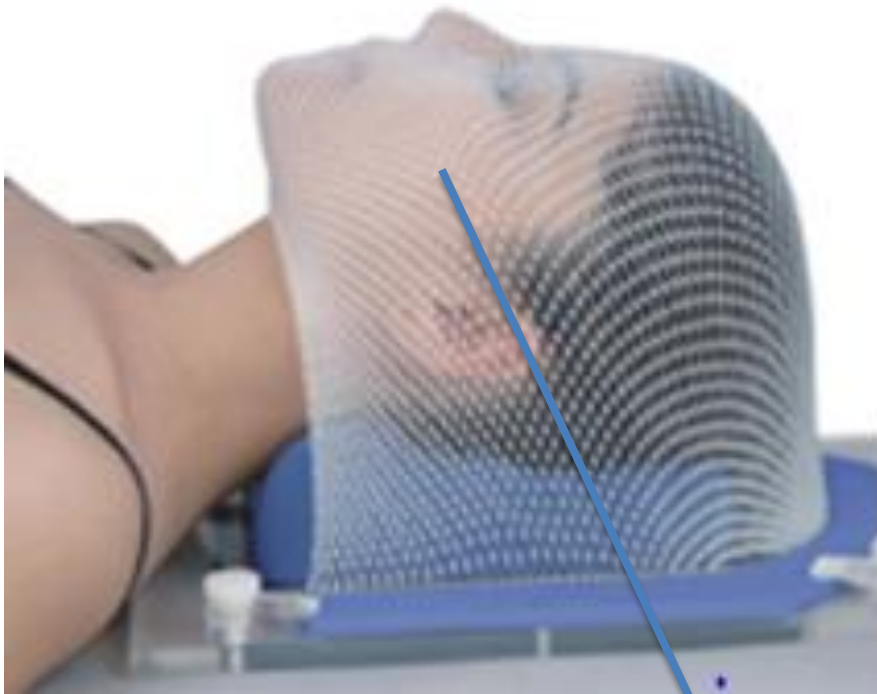


# Immobilization

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- Some Paradigm shifts are required
  - Masks
  - Positioning devices
- Patients move during treatment
- Immobilization devices often provide a false sense of security
- Its easy to blame the PPS but did the patient perhaps move?

# Some Paradigm Shifts Required - Masks



**Perforated Thermoplastic masks are;**

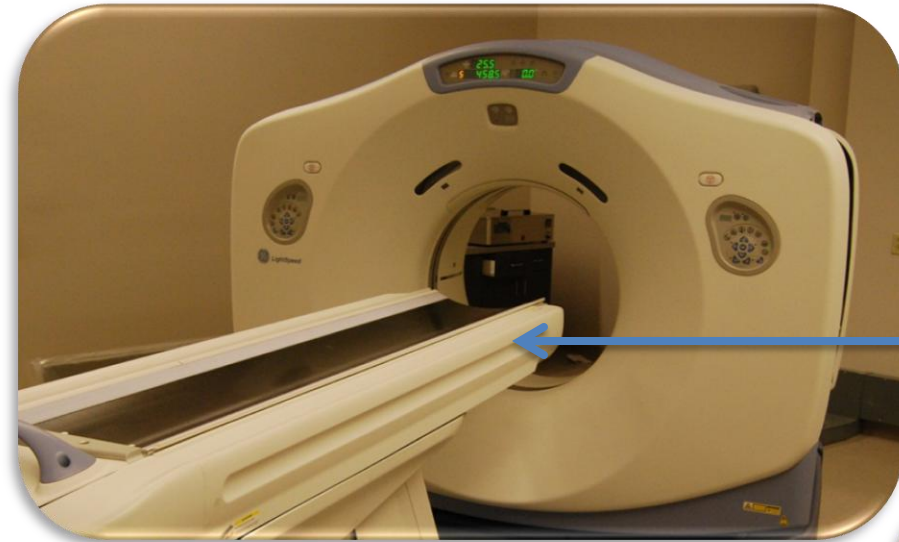
- Required in X-ray therapy to preserve the skin dose
- Not very sturdy

**Thermoplastic masks for IONS;**

- Does not affect the skin dose
- Can be thicker and more rigid.

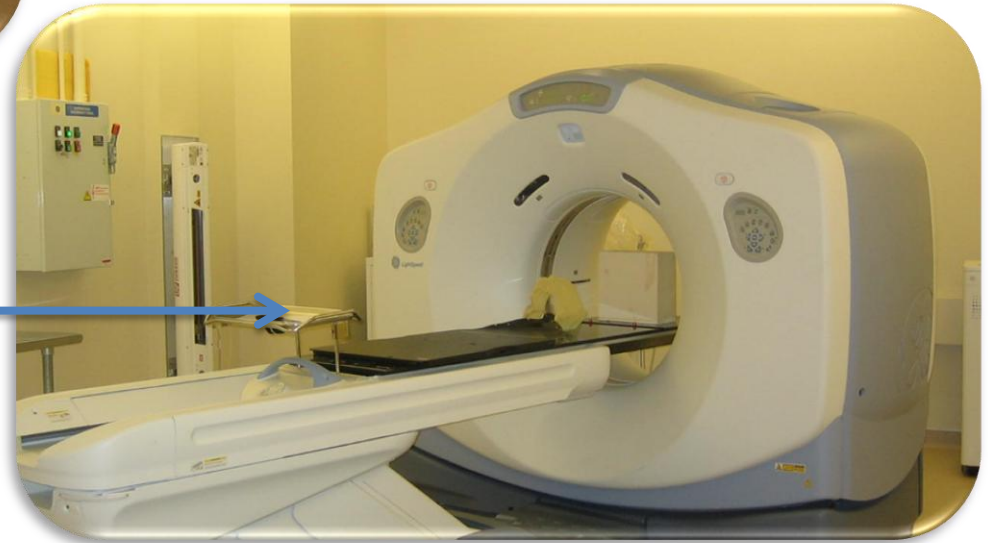
In ION Therapy the skin dose is not affected by the Mask

# Some Paradigm Shifts Required – Positioning Devices



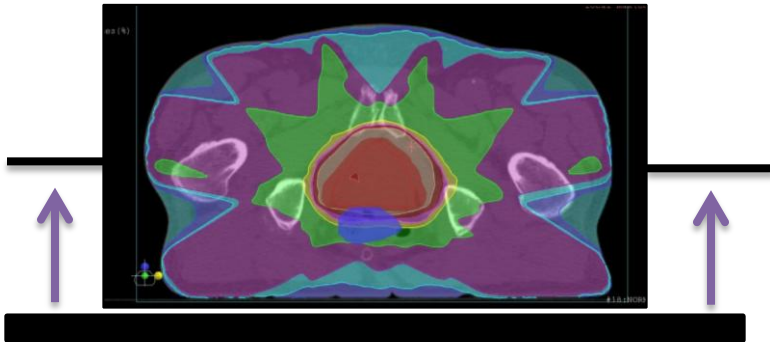
Comfortable CT Scanner top

Very Uncomfortable CT Scanner top



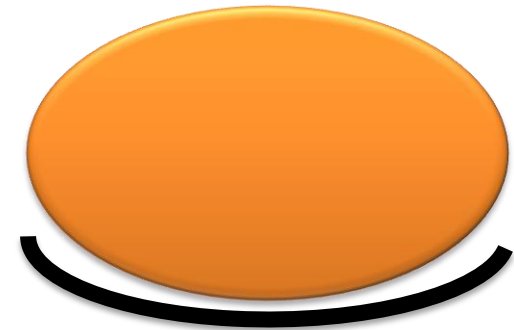
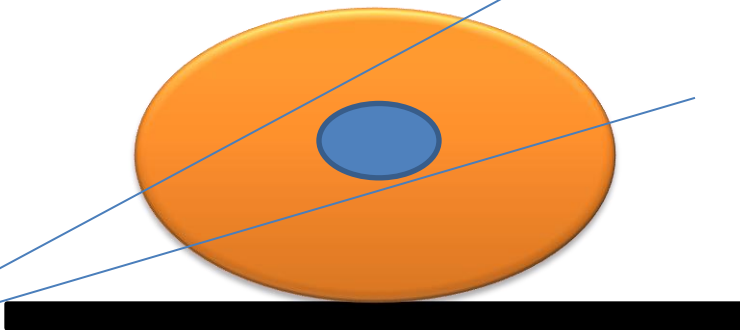
# Some Paradigm Shifts Required – Positioning Devices

## Roll correction



1. Neither the roll correction or skin dose is a problem for Ion therapy
2. We should not use flat table tops
3. The LLUMC Pods are probably the right answer

## Skin Dose

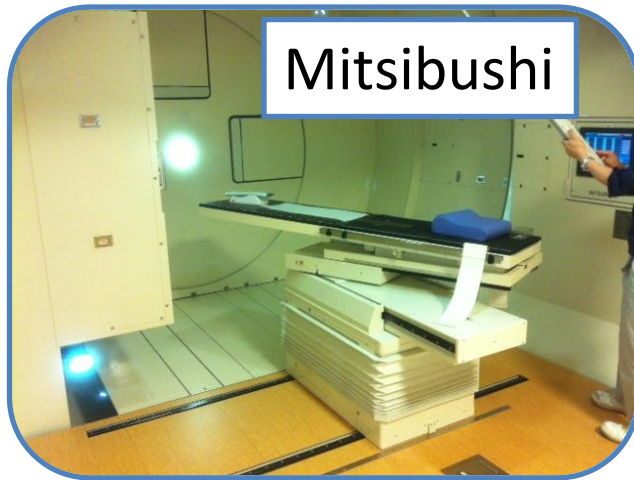
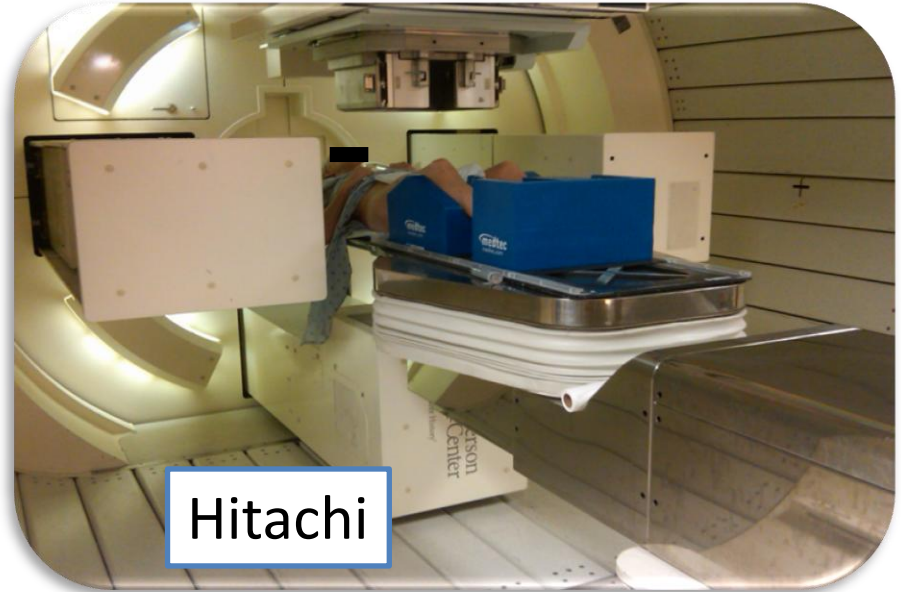
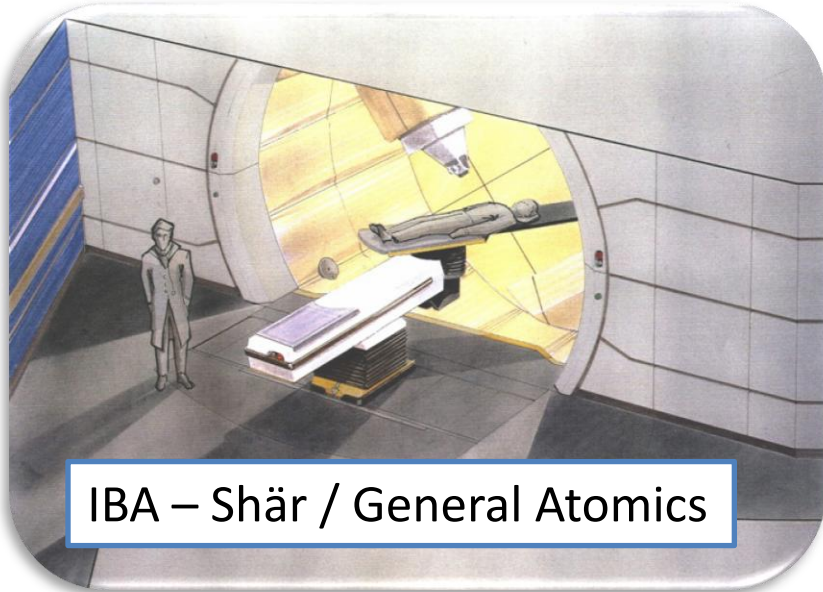


# Requirements of a Patient Positioner

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- Patient comfort
- Accuracy + Reproducibility
- Patient Safety
- Reliability
- Maneuverability
  - work envelope
  - Motion speed
- Uptime

# Custom Made Robotic Positioners



*Downside*

*Low volumes of production*

*Expensive*

*Reliability*

# First + 2<sup>nd</sup> Generation: Commercially available Robots

Use Commercially available of Robots as is



START

CPO  
1997



MPRI  
2004



Accuray  
2005



Siemens  
2005



ProCure

# Third Generation: *Everybody now use them*

2008 →



**Almost all Vendors now use a SCARA type Robotic Patient positioner**

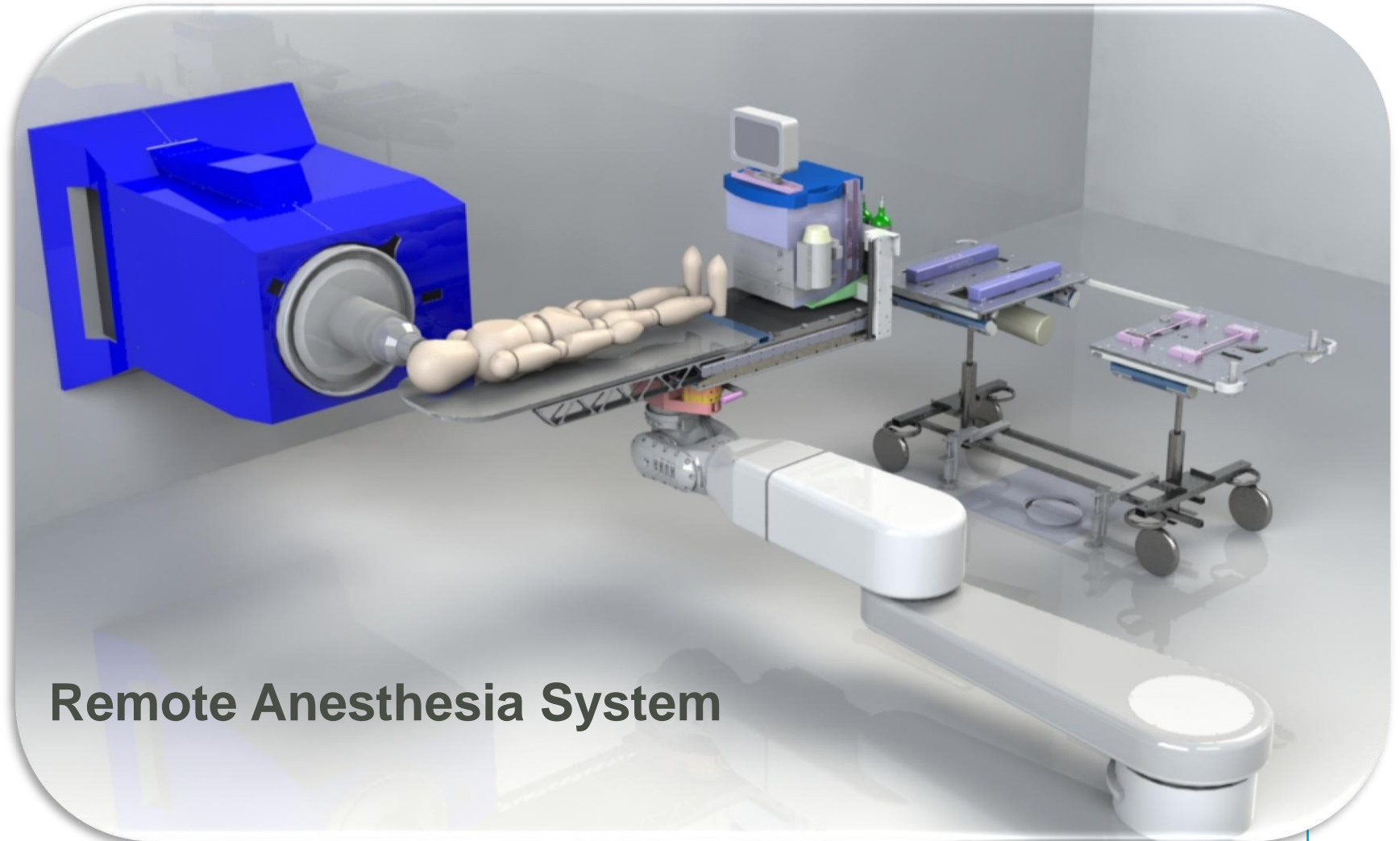


# Advantages of using a Robotic PPS

- Very reproducible – backed by a large industry
- Can couple to different disease site specific devices.
- Are reproducible + can be very accurate
- Can have large work envelopes
- Can be used by Physics in the QA environment →
- Many more
- Of course there are also disadvantages



# One example → Site Specific Treatment Devices

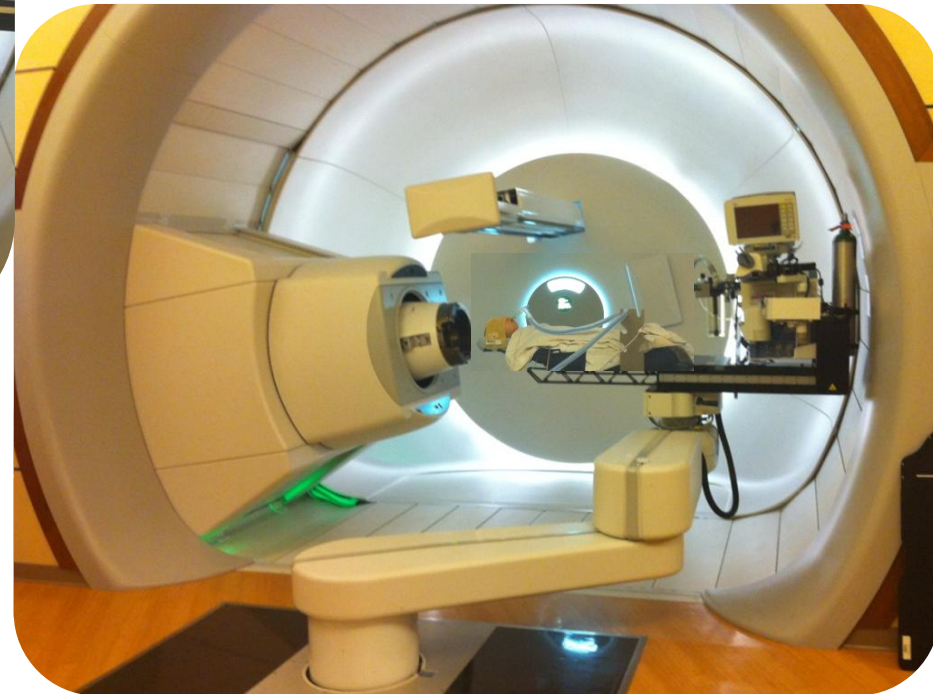


**Remote Anesthesia System**

# Site Specific Treatment Devices



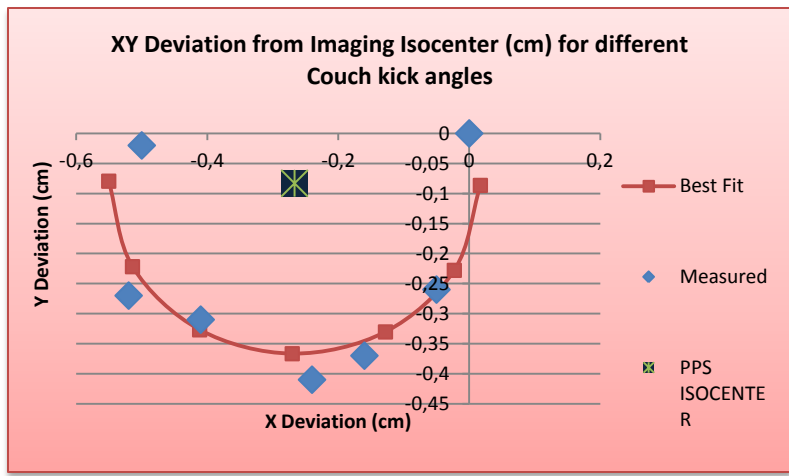
Anesthesia in the room



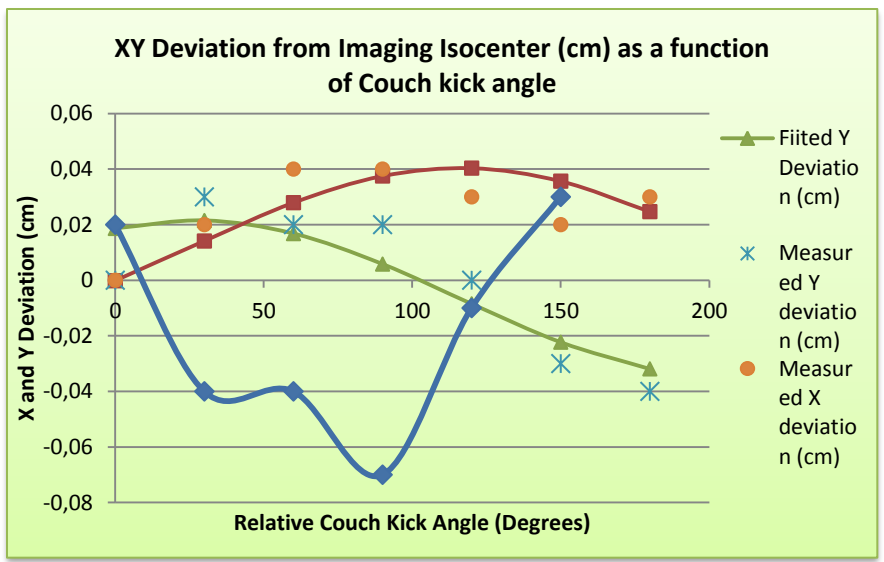
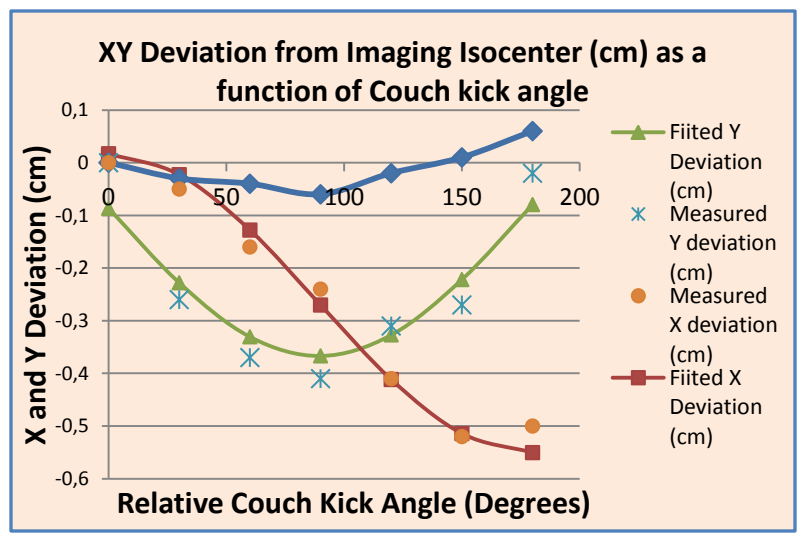
System in Clinical in use



# One potential Pitfall - Misalignment of isocenters



It does not matter how good your PPS is  
 – if the IGRT + PPS devices in the treatment room are not properly aligned all the efforts are wasted



# Next Steps – Robotic PPS

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- Smarter uses of the Robotic positioners
  - Haptic motions
  - Smart trajectories
  - Vision guidance
- Add tracking software to enlarge useable work envelopes
- Improved calibration methods
- Integrate the PPS better with PAS and Control systems

# Imaging System + Localization System

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*to know where the target is  
to ensure the target remains in position*

- Requirements
  - Dose to the patient (*if ionizing radiation is used*)
  - Resolution
  - Accuracy
  - Reproducibility
  - Ease of use / Intuitive user interface
  - Connectivity with OIS

# Target Imaging + Localization Techniques – X-Rays

## General Techniques

Surface markers – Optical tracking  
Mechanical fixation & reference frames → Indexing  
kV + MV radiographs & fluoroscopy  
Bone  
Implanted Fiducial markers  
Implantable sensors  
Surface recognition

## Volumetric / 3D

Ultrasound  
MV Tomotherapy  
In room CT scanner  
Cone-beam CT  
Megavoltage  
Kilovoltage  
MR-guided Linear Accelerator  
MR-guided Cobalt-60 Machine

# Target Imaging + Localization Techniques – **IONS**

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**Megavoltage**

Kilovoltage

**MR-guided Linear Accelerator**

**MR-guided Cobalt-60 Machine**

## **In-Situ PET Imaging**

*Adapted from Jatinder Palta*



# Overview of PAS Systems

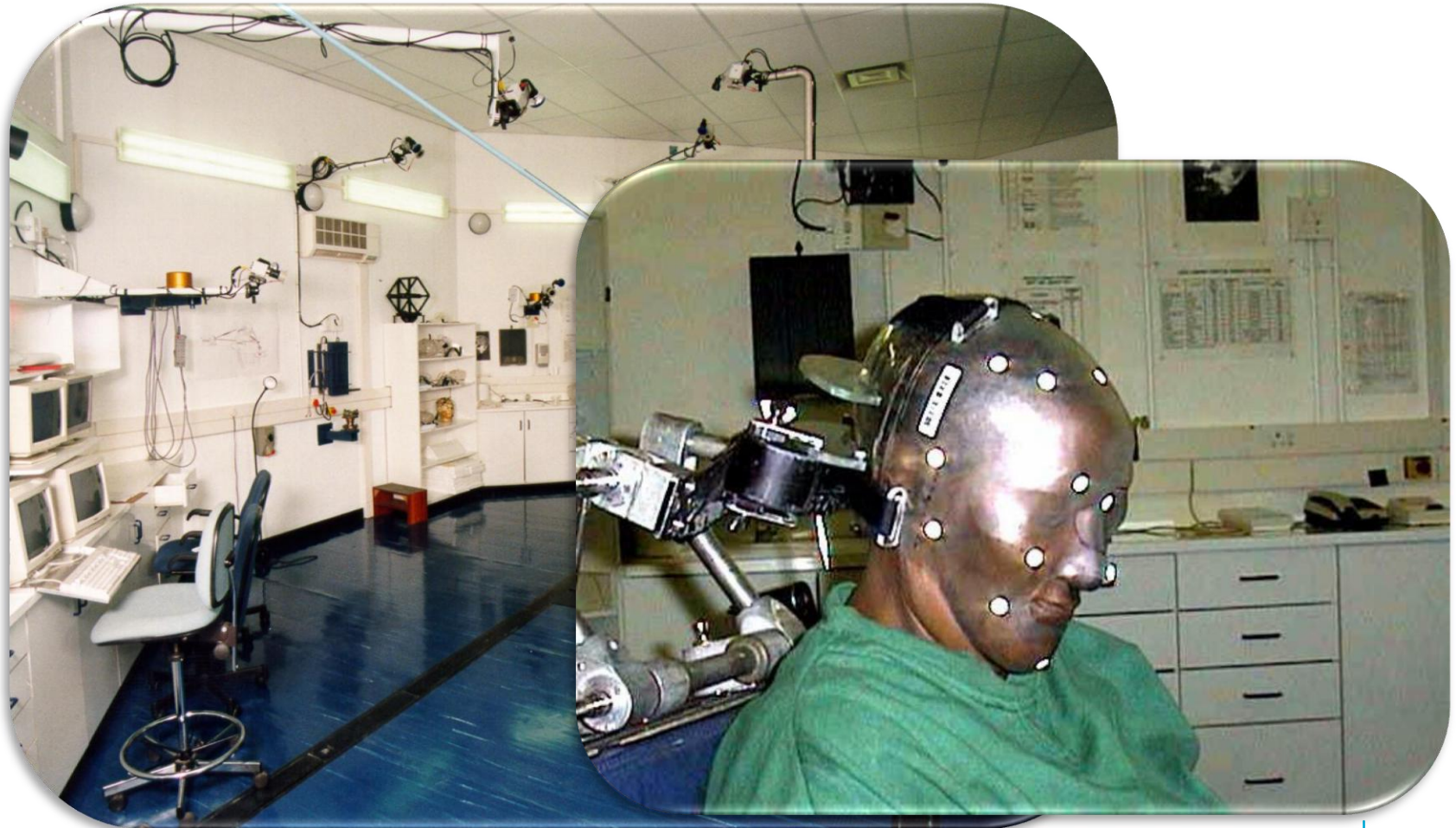
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*Existing PAS Systems used in Proton Therapy*

*Optical Tracking*  
*Surface Recognition*  
*Internal sensors*  
*Ultra Sound*  
*Planar X-Rays*  
*Volumetric Imaging*

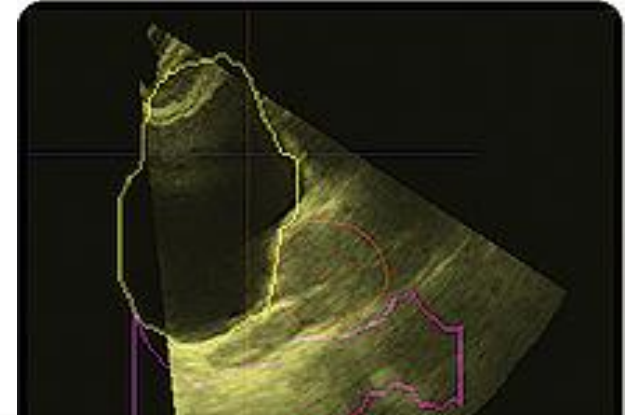
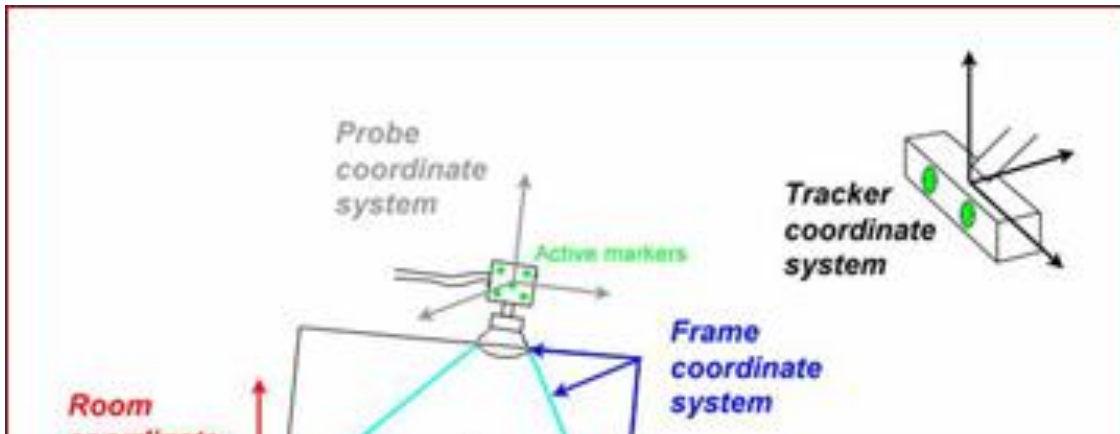
# Overview of PAS Systems – Optical Tracking

## iThemba Labs – Cape Town



# Overview of PAS Systems –Ultra Sound

## Clarity - Elekta Optical Tracking of US probe



**Elekta is working on a real time US tracking system for Prostate treatments**

# Overview of PAS Systems – Orthogonal x-rays



visions. innovations. solutions.

The screenshot displays the MEDCOM software interface for a patient named BRAIN^JOE IBL. The interface is divided into several sections:

- Top Bar:** Shows the patient name, study date (October 24, 2011), and resolution (512x512x226).
- Left Panel:** Contains patient information (Patient ID: MOS01, Name: BRAIN^JOE IBL, Date of Birth: 19691231, Machine Name: IBL, Field: 1: SETUP) and correction controls. The correction section includes sliders for X-ray images and a table for the Correction Vector.
- Correction Vector Table:**

BCM	ROBO	Translation [cm]	Rotation [°]
		0.000	0.00
		0.000	0.00
		0.000	0.00
- Main Display:** Shows a 2x3 grid of images: X-ray A, Fusion Image (Split) A, DRR A in the top row, and X-ray C, Fusion Image (Split) C, DRR C in the bottom row. A 3D model of the patient in a treatment position is visible on the right side.
- Bottom Bar:** Shows system information like 'Min: 1658HU Max: 2379HU Center: 2019HU' and the Windows taskbar.

# Overview of PAS Systems – Stereoscopic x-rays

**MEDCOM**  
visions. innovations. solutions.

**Patient**  
Patient ID: MOS01  
Name: BRAN\*JOE IBL  
Date of Birth: 19691231  
Machine Name: IBL  
Field: 1: A

**Correction Vector**

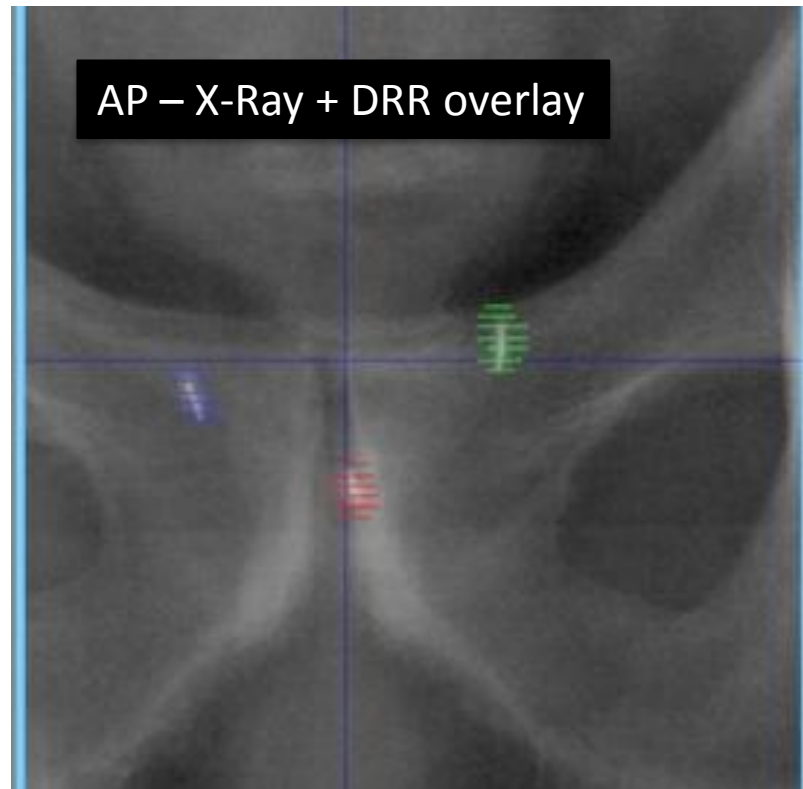
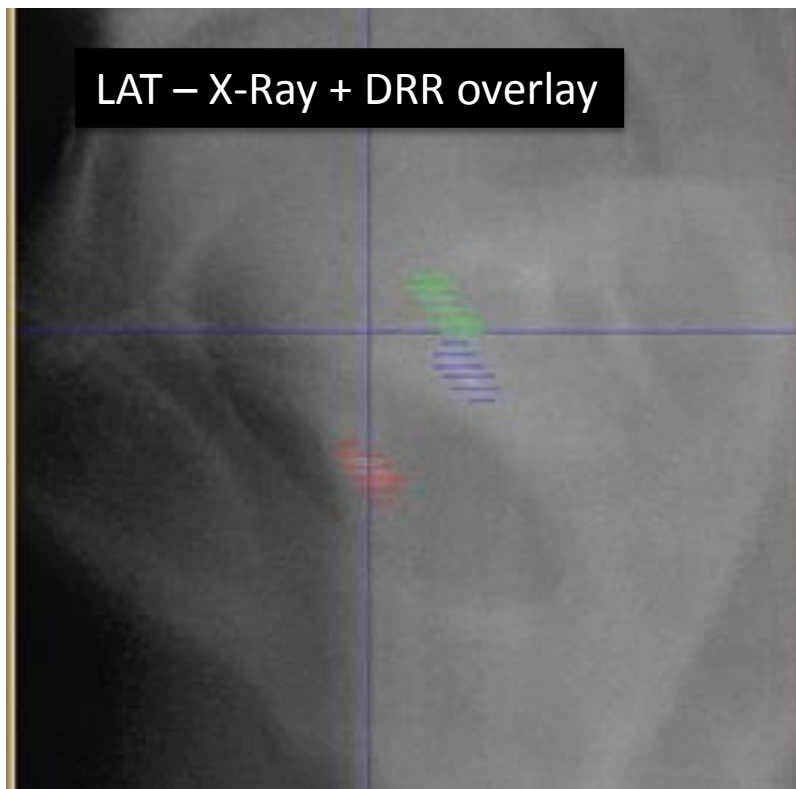
Translation [cm]	Rotation [°]
0.054	-2.88
-0.127	-0.02
-0.225	1.67

**5024.6.3 Stereoscopic X-ray**

# Overview of PAS Systems – Fiducial Markers + X-rays

## The use of Fiducial Markers - Prostate Grapes

*Contour individual Fiducial markers with a 2 mm margin*  
*Place Fiducials in the “grapes” in AP and LAT images*



# Monitoring and Motion Tracking

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- Same Technologies as in X-ray therapy should be used since the problem statement is the same.
- However - motion management is probably more important with Ions.
- Solving the motion problem is “easy” but knowing where the target is at any given moment is the challenge.

# Methods of Controlling Respiratory Motion

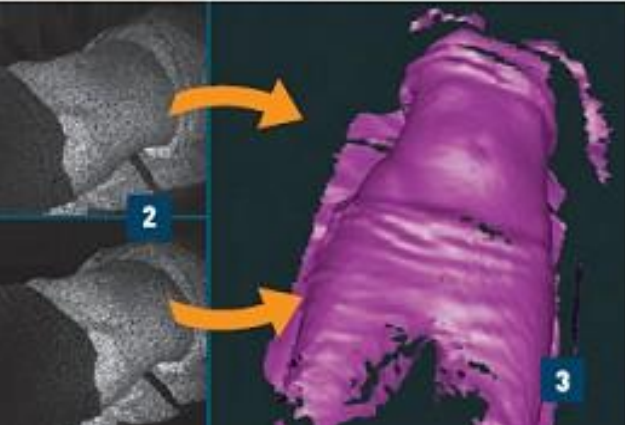
- Breath hold
  - *ABC – William Beaumont => Elekta*
  - *DIBH → MSKCC*
  - *Patient self breath hold*
- Gating – *Japanese experience*
- Countermove the entire patient – *“let the PPS breath”*
- Abdominal Compression



# Overview of PAS Systems – Surface Recognition



## Stereo Cameras



# Overview of PAS Systems – Surface Recognition

2006-07-12 11:25:36

General | Scan and tolerance settings | Image

	Absolute	Relative
Lat	-1 mm	-1,1 mm
Long	-2 mm	-2,4 mm
Vert	+502 mm	+1,9 mm
Rot	0 °	+0,4 °

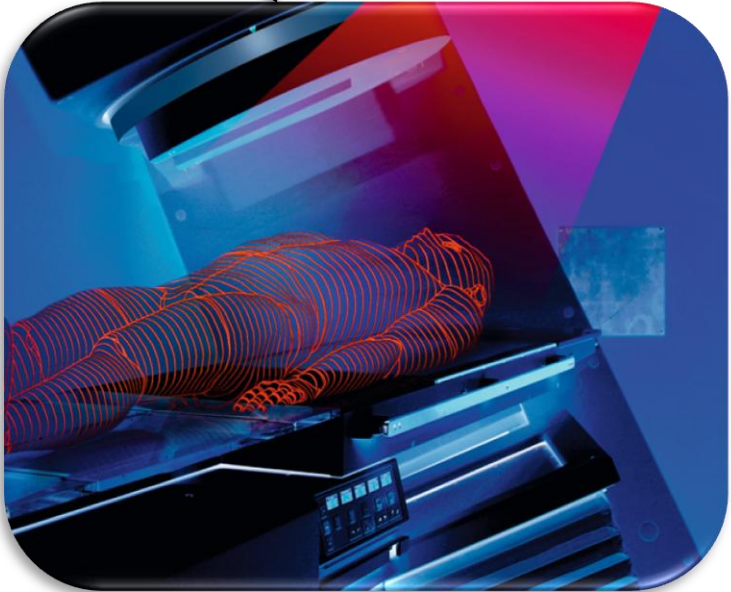
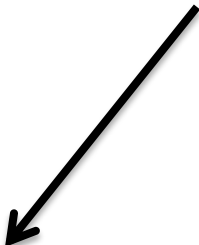
	Relative
Roll	-0,1 °
Pitch	+0,3 °

Reliability



## Laser Surface Scanners

C-RAD  
Galaxy – LAP Laser



# Overview of PAS Systems – Varian (Calypso)

N104

*P G Seiler et al*

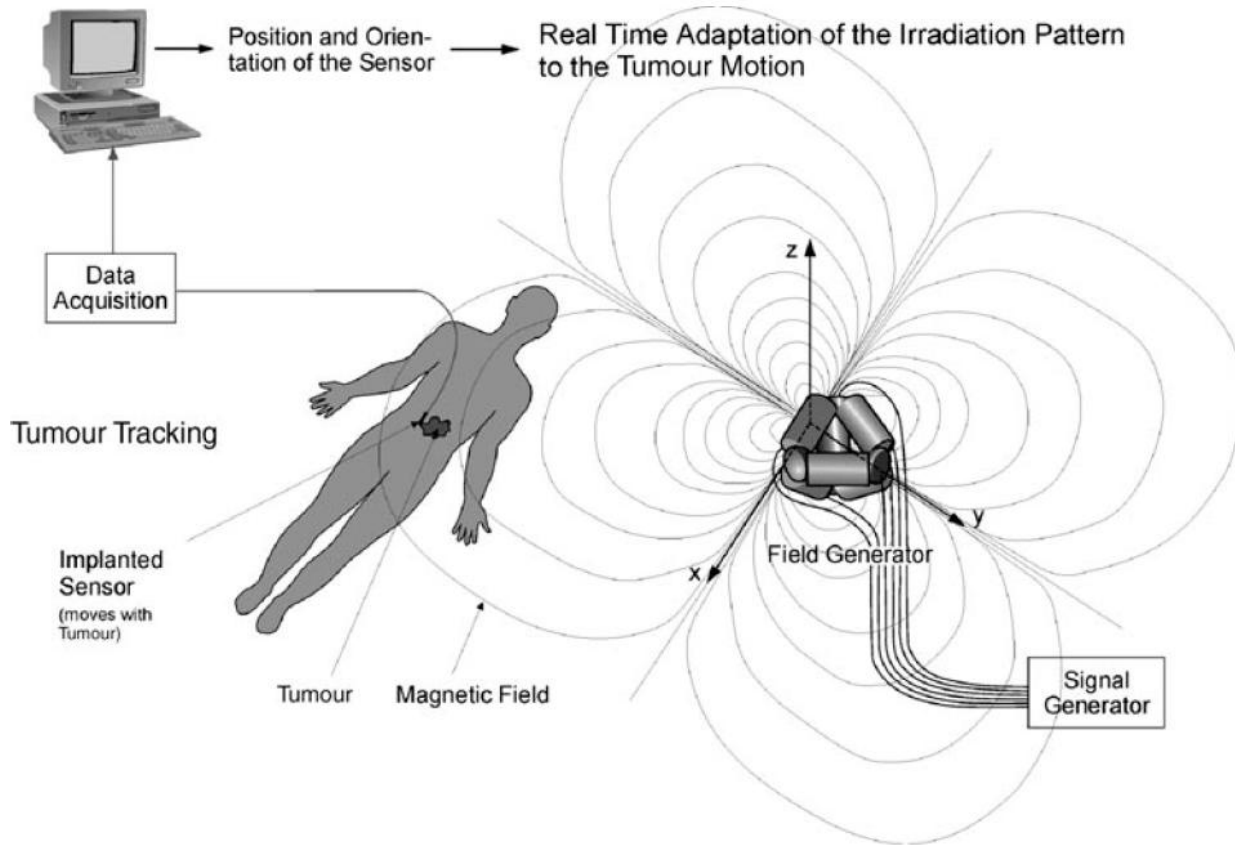


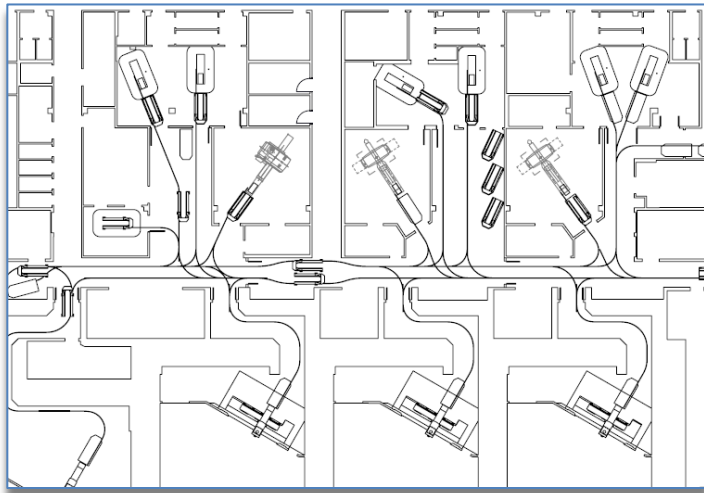
Figure 1. Schematic drawing of the TULOC assembly.

# Volumetric Imaging

- In the Photon world
  - Volumetric imaging  $\Leftrightarrow$  Cone Beam CT
  - Cone Beam CT  $\Leftrightarrow$  Image Guidance
- In the Ion Therapy world
  - Volumetric imaging  $\Leftrightarrow$  Soft Tissue Definition
  - Volumetric imaging  $\Leftrightarrow$  Anatomical characterization
  - Image quality is much more important
  - CBCT only gives a partial answer
- One solution is to use Axial CT Scanners + MRI scanners – *Inside or Outside the room*

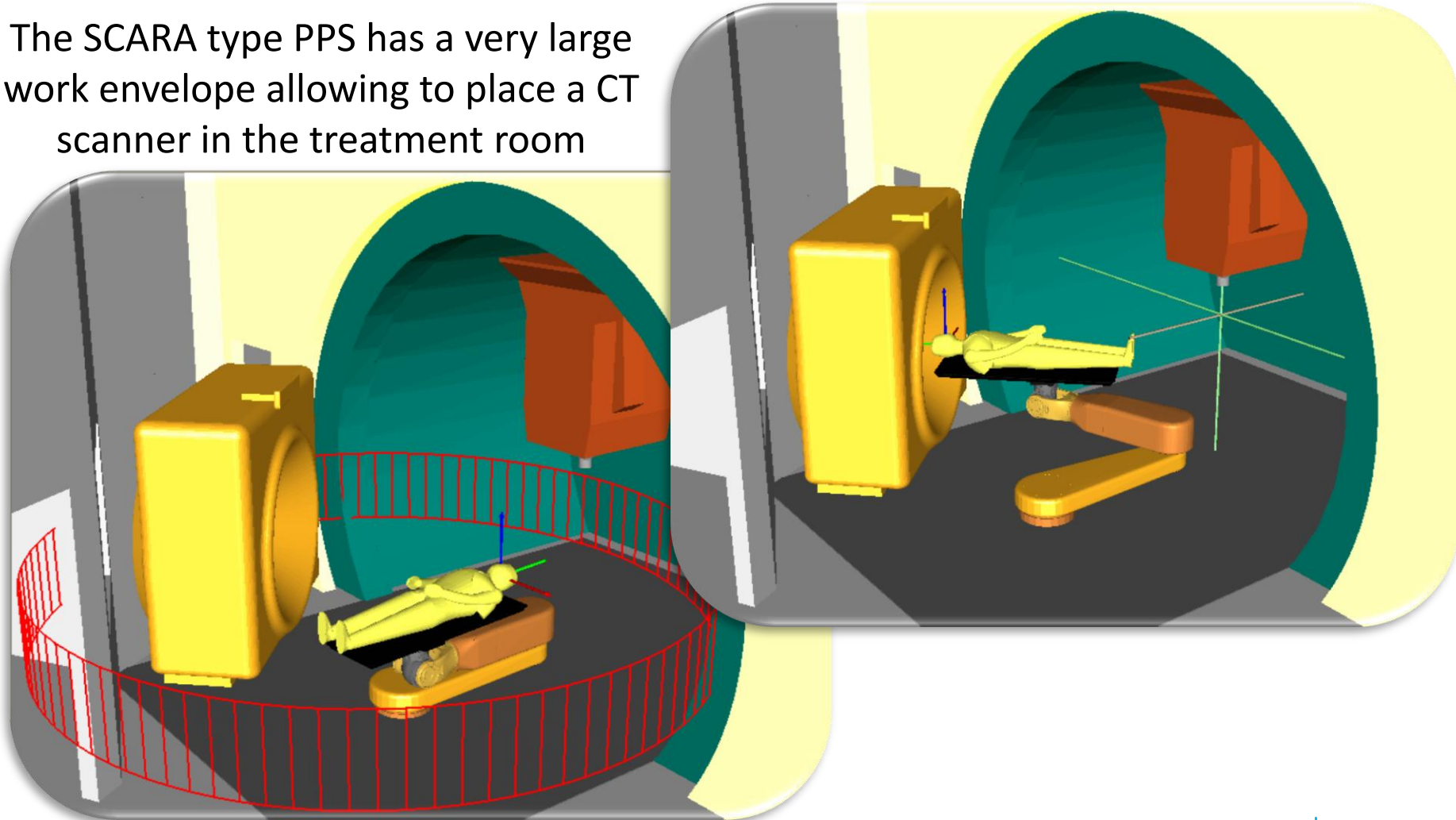
# Out of Room Options

PatLog® | PATIENT LOGISTICS SOLUTION



# In Room Options – Axial CT Scanner

The SCARA type PPS has a very large work envelope allowing to place a CT scanner in the treatment room



# In Room Options - BodyTom



“CT on Wheels”



# Summary

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- Patient Positioners based on commercially available robots are now widely adopted by most vendors.
- Unlike photons - Immobilization devices does not impact the skin dose for ion beams.
- The use of disease site specific immobilization and patient positioning devices will improve patient positioning in Ion therapy.